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Lawn Experiments

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OHIO
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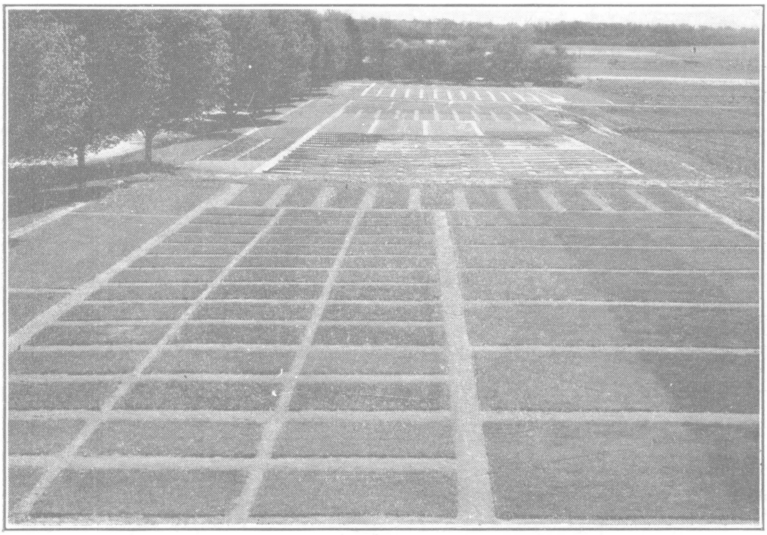

Experimental lawn plots at the Ohio Agricultural Experiment Station

LAWN EXPERIMENTS

F. A. WELTON AND J. C. CARROLL

INTRODUCTION

In this machine age, with its added hours of leisure, the importance of grass has assumed new proportions. Grass is in demand as a carpet for parks, stadia, polo fields, golf courses, and other recreational areas. In most of these places, grass must grow under highly artificial and abnormal conditions which present many new and difficult problems. To solve these problems, the Ohio Agricultural Experiment Station started experiments with turf grasses in the spring of 1927. It is the purpose of the present publication to set forth the findings to date. As in all field experiments, further work may modify or change some of the interpretations which now seem fairly well established.

ENVIRONMENTAL CONDITIONS

CLIMATE

Ohio is subject to frequent and often sudden changes of weather (1), but the climatic elements, temperature, precipitation, and snowfall, deviate so little from the normal that plants indigenous to the State rarely fail for climatic reasons alone.

The mean annual temperature of the State as a whole for the 55-year period 1883-1937 inclusive (9) was 51.1°, and the monthly mean temperatures for the growing season were: April 49.7°, May 60.5°, June 69.5°, July 73.7°, August 71.6°, September 65.6°, and October 53.4°.

The mean annual precipitation for the 84-year period 1854-1937 inclusive was 38.60 inches. The means for April, May, June, July, August, September, and October were 3.13, 3.65, 3.78, 3.79, 3.38, 2.98, and 2.59 inches, respectively. The average annual snowfall for the 47-year period 1891-1936 inclusive was 28.1 inches. According to Alexander (1) a snow covering lowers the air temperature during the night and prevents it from rising during the day, but the colder weather is more than offset by the protection snow affords low-growing vegetation.

The number of days between the last killing frost in the spring and the first killing frost in the fall ranged from 139 to 206. In general, the shortest seasons are found in northeastern Ohio. The longest are restricted to small areas adjoining Lake Erie and the Ohio River. Throughout most of the State the growing season is from 150 to 178 days.

SOIL

Ohio soils may be classed roughly as silt loam, 40 per cent, silty clay loam, 30 per cent, clay, 25 per cent, and sandy loam and miscellaneous, 5 per cent. With the exception of the more sandy and badly eroded areas, most of the soil types are suited to the successful growing of turf grasses. The soil at Wooster where all but one of the experiments reported herein were conducted is a Wooster silt loam. The subsoil is only slightly heavier than the surface soil. Below a depth of 2 or 3 feet, the soil material is a gravelly, glacial drift, much less heavy and impervious than that under many Ohio soils, such as those of the Mahoning or Trumbull series. Although the land was fairly well drained naturally, at the time it was acquired for experimental purposes in 1892 it was thoroughly tile-drained. During the 35 years preceding the starting of the lawn plots, it had been systematically limed, liberally fertilized, and carefully tilled so that it was about as uniform as any tract of land could be. The reaction of the soil was approximately neutral. One test was carried out on a silty clay loam soil at the Northeastern Experiment Farm, Strongsville, Ohio.

SEED

A combination of seeds was used in the tests on establishment and maintenance of lawns. The mixture consisted of three parts by weight of Kentucky bluegrass, one part of redtop, and one-fourth of one part of white clover. Throughout this bulletin this combination is referred to as a standard mixture. A 3 to 1 ratio of Kentucky bluegrass and redtop gives approximately the same number of individual seeds of each kind in a given volume.

ESTABLISHMENT OF TURF

PREPARATION OF SEEDBED

On subsoil.—In the establishment of a lawn, particularly around a new house, it often happens that the only material available for a seedbed is raw subsoil. Much or all of the surface soil is usually submerged during the process of excavating the cellar and the subsequent grading operations. To simulate such a soil condition, a series of plots was established on subsoil. For this series the surface soil to a depth of approximately 7 inches was removed and replaced with excavations from a new cellar. After the ground had been thoroughly packed by repeated rollings with a tractor, 10 plots, each 5 by 20 feet, were laid off with aisles 2 feet wide between. These plots were treated as indicated in table 1. The well-rotted stable manure, the black soil, and the commercial sheep manure were mixed intimately with the surface soil to a depth of 3 or 4 inches. The black soil was a loam, very dark in color, but the texture was such that it would not classify as muck. The screened cinders, sand, slag, surface soil, and limestone screenings were incorporated thoroughly to a depth of 5 or 6 inches. The 4-12-4 fertilizer added to plots 2, 6, 7, 8, 9, and 10 was applied to the surface and raked in. On April 20, 1927, the plots were seeded at the rate of 5 pounds per 1,000 square feet with the standard mixture.

The spring of 1927 was favorable for the establishment of lawn grass because of adequate rainfall at timely intervals. A fairly uniform and quite satisfactory stand was obtained on all the plots. During the first season, the growth and appearance of grass on the plot treated with well-rotted stable manure were best. The effect of the commercial sheep manure was negligible in the first few weeks, but later this plot improved, and by the end of the year it was better than the average. Perhaps the unsatisfactory results in the early stages resulted from adverse moisture relations, for the surface of the soil between rains appeared unduly dry. The effect of the black soil was practically negligible. The appearance of the grass on the plot treated with 4-12-4 fertilizer alone surpassed that of the sheep manure plot at first, but the superiority disappeared before the end of the season. Results from the plots which received not only 4-12-4 fertilizer but also various materials to ameliorate

TABLE 1.—Treatments of seedbeds on subsoil and comparative growth from them

Plot	Treatment: Material	Treatment: Per 1,000 sq. ft.	Green weight per 1,000 sq. ft., lb.: 1927: July 9	1927: July 25	1927: August	1927: September	1927: Total	Total: 1928	Total: 1929	Total: 1930	Total: 1931	4-yr. av.
1	Nothing	....	0.2	8.0	22.0	16.0	46.2	200	284	122	127	183
2	4-12-4	10 lb.	3.0	18.0	36.0	20.0	77.0	234	295	132	166	207
3	Well-rotted stable manure	500 lb.	30.0	43.0	56.0	36.0	165.0	285	310	144	164	226
4	Black soil	500 lb.	.1	8.0	23.0	18.0	49.1	190	248	116	136	173
5	Commercial sheep manure	125 lb.	1.0	13.0	50.0	27.0	91.0	238	242	112	129	180
6	Like 2 plus cinders	5 cu. yd.	33.0	32.0	59.0	23.0	147.0	201	256	117	133	177
7	Like 2 plus sand	5 cu. yd.	15.0	21.0	38.0	11.0	85.0	180	284	134	149	187
8	Like 2 plus slag	5 cu. yd.	9.0	15.0	31.0	12.0	67.0	187	300	144	163	199
9	Like 2 plus surface soil	5 cu. yd.	20.0	18.0	26.0	7.0	71.0	177	319	125	150	193
10	Like 2 plus limestone screenings	5 cu. yd.	9.0	11.0	20.0	5.0	45.0	159	269	114	156	175
	Average of 6, 7, 8, 9, and 10	....	17.2	19.4	34.8	11.6	83.0	181	286	127	150	186
Average	....	....	....	....	....	....	....	205	281	126	147	190

the mechanical condition of the new earth showed that the growth on all started a little more vigorously than on the one receiving 4-12-4 alone but that the superiority was not long maintained except on the one treated with cinders. This plot ranked next in general appearance throughout the year to the one treated with well-rotted stable manure. Cinders, however, cannot safely be recommended, for if they come in contact with underground pipes, they will corrode them. Moreover, the ashes from some kinds of coal are very toxic to plants. In view of the results obtained in this test, therefore, the use of no one of the ameliorants is warranted. On more refractory subsoils, however, it is possible that more favorable results might be obtained.

From time to time the foregoing series of plots was mowed, and at each mowing the clippings from each plot were collected and recorded in terms of pounds per 1,000 square feet. These weights, shown in table 1, reflect the effect of the various treatments, particularly in the first year of the test, 1927.

In the spring of 1928, after the first winter, the condition of all the plots was unsatisfactory, of some more so than others. At that time a regular and systematic plan of fertilization was started. It consisted of top-dressing with a 10-6-4 fertilizer at the rate of 8 pounds per 1,000 square feet three times a year, in April, June, and August. This plan was followed through the years 1928-1931 inclusive.

Supplemental seedings of redtop were made three times, on August 29, 1927, March 27, 1929, and March 10, 1930. Change in time of reseeding from fall to March was found preferable, particularly if the seed was sown in the quiet of the early morning when the ground was in a honeycombed condition. The subsequent settling of the soil provided adequate coverage and avoided the necessity of raking.

The plot to which well-rotted stable manure was added continued to lead in appearance during 1928 and 1929, but thereafter no superiority was noticeable. In fact, the continued use of the 10-6-4 fertilizer had so improved the condition of all the plots that the noticeable differences in the early stages of the test had practically disappeared by the close of 1929 and a fairly satisfactory turf had become established on all of them. The effect of the cinders, the best of the ameliorants, was hardly perceptible after the first year. In succeeding years the comparative condition of all the plots in the series was very well reflected by the quantity of grass removed from each, shown in table 1. The favorable showing made by the check plot was more apparent than real, because it supported a heavy growth of dandelions. Moreover, the series as a whole sloped gently toward this plot, and thus its position was the most favorable during periods of moisture deficiency. Since the discontinuance of fertilization of these plots in 1933, their appearance has deteriorated markedly. Continued liberal and systematic fertilization through an indefinite period, therefore, would seem to be necessary to maintain a satisfactory turf on subsoil.

On surface soil.—In a similar experiment on surface or topsoil, the treatments used were as indicated in table 2. The plots were seeded with the standard mixture on April 20, 1927. In this test there was no outstandingly favorable result from any of the treatments. In the first year, however, the plot receiving well-rotted stable manure was a little the best of all, including the one receiving commercial sheep manure as well as the one receiving a 4-12-4 fertilizer. Stable manure is, of course, a good fertilizer for grass, but the use of it on lawns frequently results in much injury, for oftentimes it carries many weed seeds. The plot to which the commercial sheep manure was added seemed to dry out unduly between rains, as it did in the subsoil test, and possibly this was the reason why the turf was only fair. The black soil treatment seemed actually to depress the growth of grass, particularly the first year.

The spreading of a mulch over the new seeding, plot 6, proved helpful. Other experiments have shown that the use of a mulch may make the difference between success and failure. Straw or any coarse green material like orchard grass or sweet clover can be used. If straw is used, it should be thoroughly shaken in order to remove weed seeds, unthreshed grain, chaff, or other foreign materials.

Applications of additional seed each fall, as on plot 7, did not prove advantageous.

Beginning in the spring of 1928, or 1 year after their establishment, all plots except the check were treated annually in April, June, and August with a 10-6-4 fertilizer at the rate of 8 pounds to 1,000 square feet for each application. The behavior of the grass in the test as a whole was accurately reflected by the green weight of clippings, shown in table 2. In this series, as in the subsoil series, the contour of the soil was such that the check occupied a favored position, since the ground sloped in its direction. Perhaps the lack of more impressive differences between the plots of the surface or topsoil series was a result of the original high level of fertility. Evidence of the superiority of the soil is afforded by comparing the average growth made on these plots in any given year with that made on those treated similarly in the subsoil series shown in table 1. The scant growth made in 1930 in the surface or topsoil series was due in part to drouth. Also, these plots were plowed up in August of that year.

SEEDING

Time.—To obtain information regarding the best time to make lawn seedings, an experiment was started in September 1927. Weekly seedings were made from September 1 to November 10, 1927, inclusive, and the following year monthly seedings were made from March to August inclusive. Beginning with the 1932-1933 test and continuing thereafter, the monthly seedings were started in December instead of March. In these winter seedings the seed was broadcast on frozen ground, and until the 1934-1935 series, no coverage was given except that which resulted naturally from subsequent freezing and thawing. In the 1934-1935 and subsequent tests, however, the seed on one-half of each plot was covered lightly by broadcasting over it good garden loam mixed with sand. The standard mixture of seeds was used each year. The plots were not watered artificially. In these annual date-of-seeding tests, all plots were allowed to stand until the following July. The latest seeding, therefore, the one made in August, was at least 11 months old when plowed up.

In these annual tests no seeding was ever a complete failure, but as might be expected, there were varying degrees of success, because the outcome of any given seeding was closely related to weather conditions, particularly rainfall and temperature. As a rule, the late summer seedings (September 1 to 22) were most satisfactory, but exceptions have occurred, particularly in seasons of dry fall weather. Occasionally, however, as in 1927 (fig. 1), and especially in 1930, the best seedings were those made in November (November 1 to 10). With the exception of 2 years, the late-sown seed did not come up in the fall. In 1931, however, on account of unusually warm weather, seedlings appeared before winter on all plots, including the latest seedings. The grass continued green until near-zero weather, 9° on February 1 and 1° on March 9, 1932, killed most of the grass except the September and early October seedings.

TABLE 2.—Treatments of seedbeds on surface or topsoil and comparative growth from them

Plot	Treatment: Material	Treatment: Per 1,000 sq. ft.	Green weight per 1,000 sq. ft., lb. 1927: July 6	1927: July 18	1927: July 25	1927: August	1927: September	1927: Total	Total: 1928	Total: 1929	Total: 1930	3-yr. av.
1	Nothing	....	86	46	30	94	59	315	400	320	91	270
2	4-12-4	10 lb.	53	43	31	82	44	253	467	368	111	315
3	Well-rotted stable manure	500 lb.	91	40	27	93	46	297	474	377	117	323
4	Black soil	500 lb.	32	29	23	64	32	180	389	312	110	270
5	Commercial sheep manure	125 lb.	71	52	27	88	33	271	473	348	102	308
6	Like 2 plus mulch at time of seeding	10 lb.	92	44	26	70	31	263	443	363	119	308
7	Like 2 plus seed each fall	....	....	....	....	....	....	....	412	342	114	289
Average	....	....	....	....	....	....	....	....	437	347	109	298

In a supplemental test made in the warm fall of 1935, the seedings made as late as November 1 reached the "fuzz" stage before winter. During the summer of 1936 this seeding was completely overwhelmed with weeds, whereas those made September 1 and October 1 were practically weed free, as shown in figure 2.

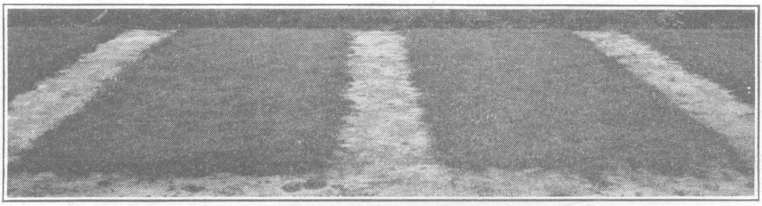

Fig. 1.—Occasionally November seedings may be as good as early spring.

Seeded March 31, 1928 (left), November 10, 1927 (right)

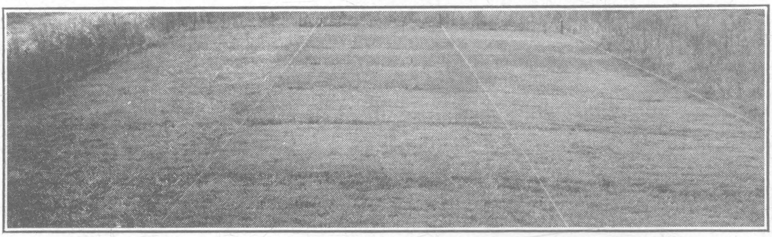

Fig. 2.—Date of seeding in warm late fall of 1935

Seeded September 1 (right), October 1 (middle), and November 1 (left). The latter is practically all weeds.

In general, the early spring seedings have been successful but not as satisfactory as those made in late summer. Even those made in March without any spring preparation of seedbed were usually successful providing the precaution was taken to cover the seed lightly where little honeycombing occurred.

A few of the midsummer seedings were successful, but most of them were not. The failures were always associated with hot dry weather. If at the time of seeding and during the seedling stage there was an abundance of soil moisture accompanied by reasonably cool weather, the seedings were a success, otherwise not. The grass failed more frequently than did the white clover. Sometimes the stand consisted almost entirely of the latter.

In the winter seedings made in December, January, and February without artificial coverage, some grass was obtained on all dates but no seeding was entirely satisfactory. From the seedings made in the winter of 1934-1935 and the winters following, however, a fairly good stand was generally obtained on that half of each plot over which a coverage of good garden loam was broadcast.

In these tests a stand of white clover was usually obtained in the first two or three September seedings, but in the later ones practically none survived the winters. When the seedings were protected by a straw mulch, a sprinkling of clover plants was obtained on all the fall seedings.

On account of the wide variations in climatic conditions from year to year, no ironclad rule can be laid down as to the best time to seed. Unfortunately, a part of the 12 years included in these tests was not altogether representative. The annual rainfall in 6 of these years was not only below the 50-year average, but was so far deficient in each as to assume the proportions of a major drouth. The results of these tests, therefore, may overemphasize the weaknesses of spring and midsummer seedings, but such as they are, they indicate that late summer, August 20 to September 20,[1] is the preferable time to seed. At this time, seasonable rains are usually forthcoming and cool weather is approaching. Relatively low temperatures apparently favor the growth of Kentucky bluegrass (3). Spring seedings are confronted with the coming of hot dry summer weather, and unless they are made early enough that the grass may become well established before the arrival of such weather, they will suffer unless copiously watered. Moreover, spring seedings must combat all the weeds of spring, summer, and fall, whereas late summer seedings have only the fall weeds with which to contend. Furthermore, if the seeding is delayed until late summer, opportunity is afforded for the preparation of a better seedbed than is usually available in the spring. If organic matter is needed and well-rotted stable manure or other similar materials are not available, a crop like soybeans or buckwheat may be grown, plowed under, and thoroughly incorporated. If the growing of a green manure crop is not necessary, clean cultivation may be practiced. Through frequent cultivating and hoeing during the summer months, most of the weed seeds will be encouraged to sprout and the young weeds killed. Also, summer rains will pack the soil thoroughly with the result that there should be available in the fall an ideal seedbed, one that is firm, fine, and clean.

Seedings made in late September or even in early October are sometimes successful, especially if the soil is rich and conditions are favorable for rapid growth. The later they are made, however, the greater is the danger of failure. A difference of a few weeks may make a marked contrast in the development of plant parts below as well as above the ground, as shown in figure 3. At least 6 weeks of good growing weather are required for grass to become safely established. If for any reason late summer seedings are impossible, the seeding should be delayed until November 10 or later in the latitude of Wooster in order to avoid germination until the following spring. Of course, this procedure is not feasible except where the contour of the ground is such that the soil will not wash, and even then in some years it would be unworkable because of November rains.

[1]In southern Ohio the corresponding date would be about 2 weeks later.

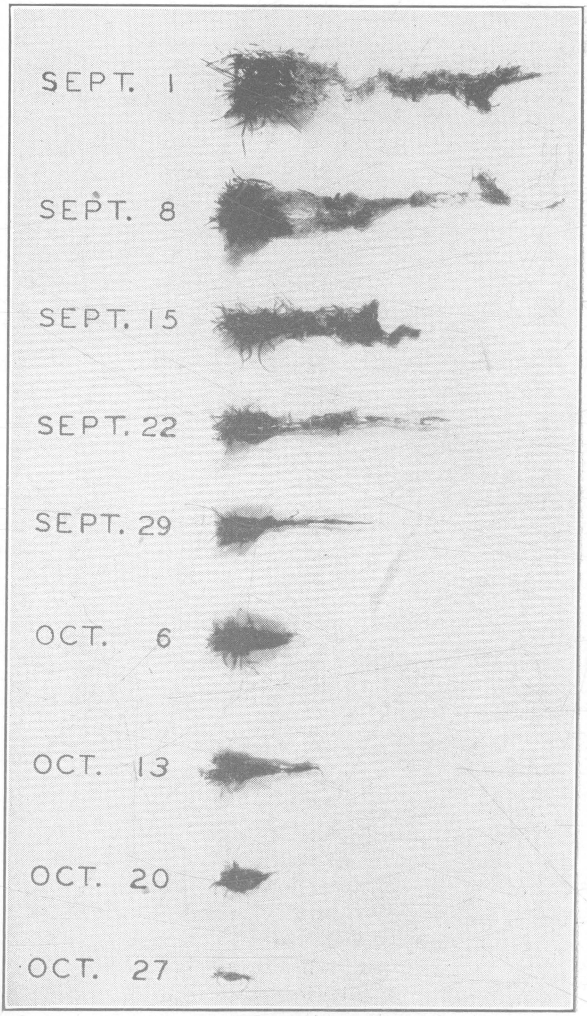

Fig. 3.—Comparative size of grass plants (roots and tops) from seedings made at weekly intervals from September 1 through October 27, 1935

Photographed December 23, 1935

Late spring and midsummer seedings are unwise and should not be undertaken unless facilities are available with which to supply water artificially and in abundant quantities if hot dry weather follows. A mulch of some coarse material free from weed seeds, like unripe plants of sweet clover or orchard grass, may make the difference between success and failure.

Rate.—In the establishment of a lawn, it is poor economy after all the other necessary work has been done, to skimp on seed, for too little seed often results in a thin, patchy stand of grass, just the kind of stand in which weeds easily become established. A thick stand in the early days of a new lawn is the best insurance against the encroachment of weeds, and a relatively thick seeding is one of the important factors in getting such a stand.

In a rate-of-seeding experiment, the standard seed mixture was sown April 20, 1927, at 10 different rates beginning at 0.7 pound per 1,000 square feet (approximately 30 pounds per acre) and ending with 11.2 pounds per 1,000 square feet (approximately 480 pounds per acre). A fair indication of the thickness of grass was obtained from the weight of the clippings made throughout the first year, and particularly from those made during July (table 3). In the first cutting, made July 6, the weight of grass increased progressively with one exception from the thinnest to the thickest seeding, but in subsequent cuttings during the remainder of the year the quantity of growth fell off in the heavier seedings, presumably because the plants were too thick. Toward the end of the first and during succeeding years, these earlier differences between plots diminished still further until finally they disappeared. In the thinner seedings, however, a considerable portion of the coverage was weeds, principally dandelions, as shown in figure 4. On the fourth (left) and following plots (not shown in illustration) there were very few dandelions.

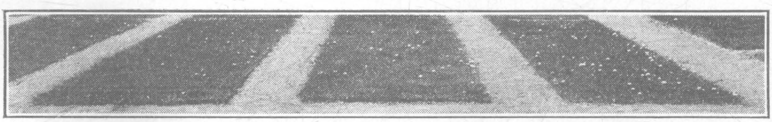

Fig. 4.—A thin seeding is an invitation for weeds

Considering the density of the stand and the general vigor of the plants in the early days of this test, the time at which the weed menace was greatest, it appears that at least 3 pounds per 1,000 square feet of the standard or a similar mixture of seeds is the minimum required to ensure prompt coverage and reasonable weed control. More rather than less would be advisable. Of course, the rate should vary according to the kind and quality of seeds.

Method.—Small areas are usually seeded by hand. Seed should be distributed evenly, and such a distribution is not possible during windy weather. Quiet is more likely to prevail in the early morning or late afternoon. It is well to divide the seed and sow one-half in one direction and the other half at right angles to it. This practice will further facilitate even distribution. It is important that the seed be covered lightly, one-eighth to one-fourth inch. A light covering can be accomplished by raking gently or by broadcasting over the seed a thin layer of screened garden loam or ground peat.

On large areas where hand sowing is impractical, a wheelbarrow seeder can be used. Coverage can be effected by the use of something like a weeder or brush drag.

TABLE 3.—Comparative growth from different rates of seeding

Plot	Seed sown per 1,000 sq. ft., lb.	Green weight per 1,000 sq. ft., lb.									
		1927						Total			3-yr. av.
		July 6	July 18	July 25	August	September	Total	1928	1929	1930	
1	0.7	17	22	18	60	35	152	397	391	147	312
2	1.4	18	26	25	65	40	174	427	390	139	319
3	2.1	22	25	27	69	32	175	395	357	121	291
4	2.8	24	24	28	64	27	167	368	325	109	267
5	3.5	40	32	29	69	30	200	403	369	129	300
6	4.2	61	33	30	77	33	234	403	395	139	312
7	4.9	63	42	32	80	33	250	409	376	143	309
8	7.0	80	44	34	94	39	291	434	360	133	309
9	9.1	79	40	30	80	31	260	400	329	126	285
10	11.2	98	39	24	75	31	267	415	352	123	297
Average	...	...	...	...	...	...	217	405	364	131	300

SODDING

In situations where seedings are liable to be destroyed before they can become established, as on terraces and steep banks subject to washing and on thin or bare spots where hard and frequent usage makes successful seedings difficult, sodding is preferable to seeding. Where the element of time is not important, however, seeding is to be preferred for several reasons. Seeding usually gives a more even surface. It ordinarily results in less weed trouble, and, most important of all, it is considerably cheaper.

Where sodding appears preferable, the soil should be prepared in the same manner and with the same care as for seeding. Due consideration must be given to drainage, organic matter, and fertility in general. Sod placed on hard, poorly drained, infertile soil is foredoomed to failure. Sod will not succeed any better than seedings in shady places, for the conditions responsible for the original failure will, unless corrected, bring about eventually the destruction of the sod.

In order to obtain a smooth surface, sod should be cut to a uniform depth, and for ease in handling and speed in establishment, the thickness should not exceed three-fourths to 1 inch. For large areas, a sod cutter drawn by a tractor or horse is ordinarily used. For small areas, however, sod is usually cut by hand. If hand-cut sod is too uneven, it can be made uniform by placing the sod, grass down, within a frame of the desired depth fastened to a table and drawing over it a sharp blade something like a drawknife.

Sod should be laid close together but neither crowded nor stretched, and the joints should be even. If the sod is cut into strips, say 1 by 3 feet, then in sodding a sloping area like a terrace, the strips are preferably laid horizontally and the joints staggered. This method results in less washing at the joints than might occur if strips were laid up and down. After it has been laid, the sod should be thoroughly watered and then carefully tamped or rolled with a medium-weight roller, one weighing 150 to 200 pounds per foot of length. Sod thus laid will send roots into a fertile seedbed in 3 or 4 days and under favorable conditions will be well established in 2 weeks.

If for any reason sod cannot be laid promptly, it is best preserved by spreading flat on the ground, grass exposed, in some shady place. In this way, sod may be kept 2 or more weeks if watered occasionally.

Sodding can be done any time during the season, but best results with a minimum of labor are obtained in late spring or early fall. If sodding is undertaken in the summer, the sod may need to be watered before it can well be moved. It should first be soaked with water 2 or 3 days and then allowed to dry until it can be handled easily.

MAINTENANCE OF TURF

To maintain a dark green dense turf with a minimum of mowing is the goal of every homeowner who takes pride in a well-kept lawn. Vegetative growth in excess of that required to give a healthy green appearance, however, is undesirable, for it merely increases the necessity of more frequent mowing. Presumably, if it were possible to maintain a greensward without any mowing, most lawnowners would be fairly well satisfied. To obtain information regarding methods of maintenance, an experiment was started in the spring of 1927 with different kinds and quantities of fertilizer and various cultural practices. These maintenance treatments are indicated in table 4. Each plot (5 by 30 feet) was subdivided into three equal parts. One-third was seeded with the standard mixture; one-third with red fescue; and one-third with the Washington strain of creeping bent. The standard mixture and red fescue were seeded April 19. The bent stolons were planted April 28. The effect of the various treatments is fairly well indicated by the clipping weights, which are shown also in table 4. After 1928, the weights were based on the growth of two sections only, red fescue and standard mixture, and in 1932 on the standard mixture section alone, as the red fescue section was ruined in 1931 by sod webworms.

SOIL TREATMENTS

Lime.—An annual application of hydrated lime at the rate of approximately 100 pounds per 1,000 square feet proved detrimental. The turf was not dense and thick but more or less open and broken. As can be seen from table 4, the growth of grass was moderate only, for the 5-year average green weight was no better than that of the check. Perhaps this result was to be expected because the lime was applied so liberally, but it was applied no more lavishly than is done by many homeowners, for some of them practically whitewash their lawns every spring. The inferiority of the grass probably was not entirely due to the acquired alkaline reaction of the soil. Such heavy applications of hydrated lime tend to collect in bunches, crust over, and thus smother the grass, leaving the turf broken and patchy. Mixing with some material like good garden loam or screened sand will in a measure obviate this result.

On sour soil the use of lime on lawns may cause a notable improvement in the appearance and growth of the grass. At Strongsville, for example, on soil with a reaction of pH 5.1, limestone used at the rate of 100 pounds per 1,000 square feet resulted in the development the following year of grass relatively dark green in color, and the growth in one season, 1932, was 78 per cent greater than that on an equal and adjoining but unlimed area. On a sour soil like this it is helpful to apply lime. Annual top-dressings are not required. Moderate applications 8 to 10 years apart should suffice. More than 75 pounds of hydrated lime or 100 pounds of limestone per 1,000 square feet in any one season should be avoided. In excessive quantities lime may result in conditions temporarily unfavorable for optimum growth.

It is true that a soil rich in limestone favors the growth of certain weeds, particularly dandelions, but it is also true that a sour soil favors the growth of certain other weeds, such as sorrel. It would seem, therefore, that alteration of the reaction of the soil is of little value in controlling weeds. A better plan is to make soil conditions as favorable as possible for the growth of the particular grasses used and then, if weeds appear, to apply a specific remedy for the particular weed or weeds present.

Grasses differ in their demands for lime, some requiring a less acid soil reaction than others. For the thrifty growth of Kentucky bluegrass the reaction should not be more acid than pH 6. Most of the fescues and bents, however, are more acid tolerant. They may thrive with a reaction of pH 5.5 or even pH 5. Few grasses can endure as high acidity as a pH of 4 represents, as was shown in a reaction test representing seven levels of acidity varying from pH 4 to pH 8. In this test, located on good soil and continued through 8 years, none of the 14 grasses made satisfactory growth on the plots with a reaction of pH 4.

TABLE 4.—Effect of various maintenance treatments on lawn turf

Plot	Treatment: Material	Treatment: Per 1,000 sq. ft.: Per application	Treatment: Per 1,000 sq. ft.: Per yr.	Green weight per 1,000 sq. ft., lb.: 1928	1929	1930	1931	1932	5-yr. av.
		Lb.	*Lb.*						
1	Nothing	....	....	148	181	78	150	104	132
2	Hydrated lime in April	104	104	161	156	86	134	92	126
3	Ammonium sulfate in April	4	4	192	198	117	143	139	158
4	Steamed bone in April	15	15	172	224	95	132	199	164
5	Ammonium sulfate in April	12	12	299	291	153	222	216	236
6	Ammonium sulfate in April, June, and August	4	12	257	278	147	222	199	221
7	Ammonium sulfate in April, May, June, July, August, and September	4	24	345	396	187	283	242	291
8	10-6-4 in April, June, and August*	8	24	284	304	210	274	231	261
9	Like 8 plus ground limestone every 4 years†	8	24	297	292	187	230	224	246
10	Like 8 plus compost in the fall	8	24	325	328	207	267	247	275
11	Like 8 plus clippings	8	24	442	516	249	317	315	368
12	Like 8 but mowed twice normal frequency	8	24	290	270	194	231	202	237
13	Like 8 plus late mowing in fall (November 1 or later)	8	24	303	271	172	218	203	233
14	Like 8 but plot not rolled in the spring	8	24	314	274	172	236	223	244
Average	....	....	....	273	284	161	219	203	228

*Nitrogen in ammonium sulfate, phosphorus in 20 per cent superphosphate, and potassium in muriate of potash.
†Ground limestone at the rate of 50 lb. per 1,000 sq. ft.

On loam soils, which constitute about 70 per cent of the total in the State, the approximate quantity of hydrated lime required to reduce the acidity to a depth of 3½ inches to pH 6, the minimum for best growth of Kentucky bluegrass, is approximately as follows:

From pH 4.5,	40 to 45 pounds per 1,000 square feet
From pH 5,	25 to 30 pounds per 1,000 square feet
From pH 5.5,	10 to 15 pounds per 1,000 square feet

On soils heavier than loams (clays) more lime is required, and on those lighter than loams (sandy types) less is needed. If limestone is used, approximately one and one-half times the quantities already mentioned would be required. In top-dressing an established lawn with lime it is preferable, when the hydrated lime is used, to split the application with a few months intervening if the quantity required is in excess of 75 pounds per 1,000 square feet. The reaction of any soil will be determined free of charge if a pint sample is sent to the Department of Agronomy, Ohio Agricultural Experiment Station, Wooster, Ohio. Also, recommendations will be made concerning the proper amount of lime to be applied to bring the soil to the desired pH value.

Lime can be applied at any season of the year, but inasmuch as its action is at best slow, fall, winter, and early spring are the most favorable times. Then, penetration into the soil is most rapid because of the freezing and thawing weather of winter and spring. If lime is to be applied at the time a lawn is established, it should be worked in thoroughly to a depth of 4 or 5 inches. This method ensures even distribution and places the lime in the soil horizon occupied by the bulk of the grass roots.

Steamed bone.—An annual application of steamed bone at the rate of 15 pounds per 1,000 square feet resulted in the development of a fairly dense turf. It did not increase materially the quantity of grass, as can be noted by referring to table 4, and the foliage was neither luxurious nor exceptionally dark green in color. The action of this material is relatively slow. Its effect, however, is cumulative, for in the fifth or last year of the test, 1932, the quantity of growth was higher than in any other year of the 5-year period except 1929. The growth made by every one of the other 13 plots of the series was the lowest the last year of the test. White clover was more prevalent on the steamed bone plot than on many of the others.

Inasmuch as steamed bone carries chiefly phosphorus and only a relatively small portion of nitrogen, its use should usually be accompanied by a carrier or carriers of nitrogen like ammonium sulfate alone or preferably ammonium sulfate and an organic like soybean meal. A mixture consisting of one part steamed bone, one part ammonium sulfate, and three parts soybean meal would on most soils give an appreciably better result than steamed bone alone.

Steamed bone also contains considerable calcium. On lawns, therefore, composed chiefly or entirely of bents or fescues, species which thrive well on somewhat acid soils, steamed bone should not be used unless the soil is so sour that the addition of some lime would be beneficial even to these grasses.

Ammonium sulfate.—The effect of ammonium sulfate applied annually in the spring (April) at the rate of 4 pounds per 1,000 square feet was small and always of short duration (plot 3, table 4). Even when it was applied at the rate of 12 pounds per 1,000 square feet in the spring, as on plot 5, table 4, the effect of one application did not endure throughout the season. Where the same quantity was applied in split applications in April, June, and August, the total growth produced was not greatly different, as shown by plots 5 and 6, table 4. The growth and visible effect were more uniformly distributed, however, as illustrated in figure 5, which gives a comparison of the two methods of application in each of the 5 years of the test. Although three applications made a perceptible improvement in the color of the grass, the effect from six applications, one each month, was much more pronounced, as shown by the dark shade of green on plot 7, figure 6.

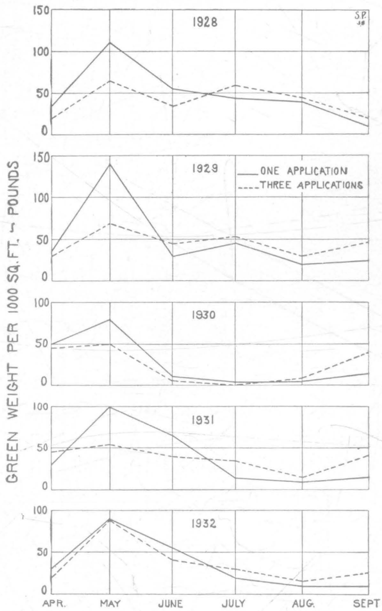

Fig. 5.—**Ammonium sulfate applied at rate of 12 pounds per 1,000 square feet annually in one application (April), in split applications (April, June, and August)**

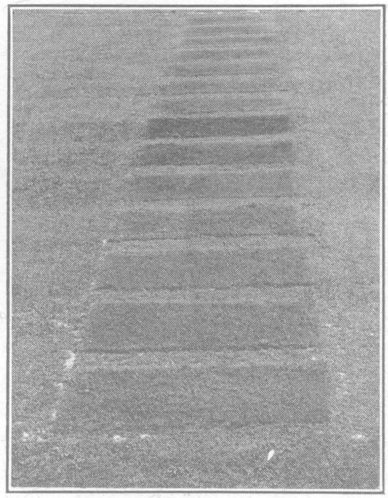

Fig. 6.—**Monthly applications of ammonium sulfate at the rate of 4 pounds per 1,000 square feet maintain a green appearance on Kentucky bluegrass throughout the summer, as indicated on plot 7.**

Photographed August 31, 1932, The rainfall for that month was 58 per cent of the normal.

Where improvement is desired promptly and the work involved in repeated and frequent applications is not objectionable, the use of a readily soluble inorganic like ammonium sulfate is recommended, since such a material deepens the color of grass quickly and promotes rapid vegetative growth. Great care, however, must be exercised in the use of this material, for unless it is applied in small quantities and evenly distributed, it may burn severely or even kill the grasses. Copious watering immediately following the distribution of this fertilizer will aid materially in avoiding scorching. Frequent applications of this material should be accompanied by an occasional top-dressing of lime in order to maintain a suitable soil reaction.

Mixed fertilizer.—Plots 8 to 14 inclusive (table 4) were fertilized three times each year with a 10-6-4[2] at the rate of 8 pounds per 1,000 square feet. They thus received the same quantity of nitrogen as did plot 6. Plot 8, however, is the only one of the group of seven on which the cultural practices fol-

[2]Made from ammonium sulfate, 20 per cent superphosphate, and muriate of potash.

lowed were the same as on plot 6 and, hence, is the only one which is strictly comparable with it. The color of turf on plot 8 was never as dark green as that attained at times on plot 6. The density of turf, however, was quite as satisfactory, and there was a greater admixture of white clover. The total growth both above and below ground was somewhat greater. The comparative aboveground growth, shown in table 4, exceeded in each of the 5 years that on plot 6. The root growth was also greater.

Root growth.—In order to note the effect on root development of the more important maintenance treatments, the quantity of roots and rootstocks was determined in 2-inch horizons on the plots indicated in table 5. The root growth on all plots except the one receiving hydrated lime was greater than that of the check and was greatest for the three receiving a 10-6-4. As stated before, plot 8 is the only one strictly comparable, on a nitrogen basis, to plot 6, and the greater root growth, therefore, must be attributed to the phosphorus or potassium or possibly both. Reid (10) found that both these elements increased the growth of roots of bent grass. If the gain in root growth were due to phosphorus alone, then it would seem that the steamed bone plot should lead plot 8, for it received about nine times as much phosphorus, but since it received less nitrogen, it is, of course, not strictly comparable. The results as a whole, including the below as well as the aboveground development, indicate that a lawn fertilizer should carry phosphorus and potassium as well as nitrogen. That lawn grass removes appreciable quantities of all three elements is shown by the composition and annual growth of one of the most common species, Kentucky bluegrass.

TABLE 5.—Effect of maintenance treatments on underground growth (roots and rhizomes)
Standard mixture

Soil horizon	Dry weight per 1,000 sq. ft., lb.*							
	1	2	4	6	7	8	11	12
				Ammonium sulfate				
	Nothing	Hydrated lime, 104 lb. per 1,000 sq. ft. in April	Steamed bone, 15 lb. per 1,000 sq. ft. in April	4 lb. per 1,000 sq. ft. in April, June, and August	4 lb. per 1,000 sq. ft. in April, May, June, July, August, and September	10-6-4, 8 lb. per 1,000 sq. ft. in April, June, and August	Like 8 but with clippings returned	Like 8 but mowed twice normal frequency
First 2 in......	64.29	56.61	67.46	71.69	68.52	93.39	96.83	98.15
Second 2 in.....	5.03	6.61	8.47	7.14	7.67	10.85	9.52	9 79
Third 2 in......	4.23	3.17	2.91	3.17	3.97	5.03	4.50	4.23
Fourth 2 in.....	2.38	1.59	1.67	1.85	2.12	2.91	2.38	2.12
Total 8 in......	75.93	67.98	80.51	83.85	82.28	112.18	113.23	114.29

*Values based on material washed from volume of soil 5 ft. long, 2 in. wide, and 2 in. thick. To remove last traces of adhering soil particles, the material, after drying, was ashed at a low red heat. The loss by ignition was regarded as the approximate weight of roots.

Composition of Kentucky bluegrass.—In 1930, 1931, and 1932, composite samples of grass clippings were gathered monthly from the standard mixture section of certain plots in the maintenance series. Although redtop and white clover had been included in the original seeding, these plants had almost disappeared, and the bulk of the growth at the time of sampling was Kentucky bluegrass. Determinations of the nitrogen content of the clippings were made each year, and in the last year determinations of phosphorus and potassium also. The results, given in table 6, show that the composition is modified not only by the addition of the fertilizer but somewhat also by the season of the year. The addition of nitrogenous fertilizer increased the nitrogen content of the grass in direct proportion to the quantity added. Accompanying this increase was a decrease in percentage of both phosphorus and potassium. The decrease in potassium was somewhat irregular. In general, the phosphorus content was lower in the spring and fall than in the summer, and the maximum was reached in August. On the average, the percentage of nitrogen was approximately nine times that of phosphorus and twice that of potassium.

Nutrient elements removed by Kentucky bluegrass.—The quantity of nitrogen, phosphorus, and potassium removed annually in the clippings was considerable, as shown in table 7. It was less on the check than on any of the fertilized plots. The increase on the fertilized plots was due in part to an increase in percentage composition and in part to an increase in growth of grass. Of the plots from which the clippings were removed, i. e., all of them except plot 11, the ones receiving six monthly applications of ammonium sulfate removed the most of the three elements. The quantities, however, were less than they would have removed from plot 11 if the clippings had not been returned to that plot. The total nitrogen, phosphorus, and potassium removed in the grass clippings per 1,000 square feet averaged for all the plots (both fertilized and unfertilized) 2.28 pounds, 0.24 pound, and 1.17 pounds, respectively. How much of these constituents came from the fertilizer it is impossible to say. To replace that removed from the check plot, all of which must have come from the soil, however, would require 9.5 pounds of a fertilizer analyzing roughly 10-3-8. It does not, of course, follow that a good lawn fertilizer must be compounded in that ratio, for in practice one must fertilize according to the needs of the soil rather than on the basis of the composition of the grass.

The proportion of the constituents required will vary, because the soils themselves are dissimilar, not only in the composition of the rocks from which they were derived, but also in the management and treatment to which they have been subjected by man. On the principal soil types of Ohio, well distributed over the State, fertility investigations have been conducted, and these studies reveal that practically all are deficient in phosphates but that most are fairly well supplied with potash. It is of major importance that the phosphate deficiency be met, for one of the important roles played by this constituent in the metabolism of grass is to promote root development. It is impossible to obtain satisfactory top growth without a good root system. The need for potash as a nutrient is, on most Ohio soils, less urgent, but inasmuch as its presence may exert a favorable influence on the vigor and vitality of the grass by increasing its resistance to disease and adverse conditions in general, the inclusion of a little in most, if not all, lawn fertilizers is commendable. On soils strikingly deficient in phosphates and, therefore, usually classed as poor, or even on those in a fair state of fertility, a mixture containing a relatively high proportion of phosphate, something like a 4-12-4, applied at the rate of 10 to 20 pounds per 1,000 square feet is usually beneficial. On relatively fertile soils, where the problem is largely one of maintenance rather than one of building up, the proportion of nitrogen to the other nutrients may well be increased, and something like a 10-6-4 used at the rate of 8 to 10 pounds per 1,000 square feet.

TABLE 6.—Composition month by month of Kentucky bluegrass

Plot	Treatment			Content of fertility elements in grass																	
	Material	Per 1,000 sq. ft.		Nitrogen (3-yr. av.)						Phosphorus (1 yr.)						Potassium (1 yr.)					
		Per application	Per yr.	May	June	July	August	September	Av.	May	June	July	August	September	Av.	May	June	July	August	September	Av.
		Lb.	*Lb.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1	Nothing	....	....	3.10	2.75	3.06	3.02	2.73	2.93	0.36	0.43	0.46	0.46	0.33	0.41	2.14	1.66	1.99	1.88	1.47	1.83
3	Ammonium sulfate in April	4	4	3.77	2.73	3.05	3.05	2.88	3.10	.37	.40	.43	.48	.33	.40	1.86	1.66	1.86	1.80	1.40	1.72
5	Ammonium sulfate in April	12	12	4.51	3.15	3.20	3.24	3.08	3.43	.35	.34	.42	.44	.29	.37	1.88	1.41	1.74	1.72	1.40	1.63
6	Ammonium sulfate in April, June, and August	4	12	3.47	2.93	3.45	3.33	3.80	3.40	.35	.34	.32	.44	.31	.35	1.98	1.72	1.83	1.84	1.28	1.73
7	Ammonium sulfate in April, May, June, July, August, and September.	4	24	4.04	3.33	3.82	4.03	3.85	3.81	.34	.29	.33	.39	.29	.33	1.90	1.66	1.55	1.84	1.39	1.67
8	10-6-4 in April, June, and August	8	24	3.82	2.89	3.63	3.43	3.31	3.41	.39	.38	.38	.46	.32	.39	2.08	2.00	1.89	1.92	1.34	1.85
11	Like 8 plus clippings	8	24	3.91	3.32	3.83	3.37	3.19	3.52	.43	.38	.43	.49	.32	.41	2.24	2.02	2.18	1.88	1.40	1.94
	Average	....	....	3.80	3.01	3.43	3.35	3.26	3.37	.37	.37	.40	.45	.31	.38	2.01	1.73	1.86	1.84	1.38	1.77

TABLE 7.—Nutrient elements removed month by month by Kentucky bluegrass

Plot	Treatment			Fertility elements in grass per 1,000 sq. ft.											
	Material	Per 1,000 sq. ft.		Nitrogen						Phosphorus					
		Per application	Per yr.	May	June	July	August	September	Total	May	June	July	August	September	Total
		Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
1	Nothing	....	....	0.35	0.17	0.19	0.09	0.15	0.95	0.041	0.027	0.029	0.014	0.018	0.129
3	Ammonium sulfate in April	4	4	.70	.20	.22	.13	.17	1.42	.069	.029	.031	.020	.019	.168
5	Ammonium sulfate in April	12	12	1.48	.40	.24	.11	.15	2.38	.115	.044	.032	.015	.014	.220
6	Ammonium sulfate in April, June, and August	4	12	.82	.33	.36	.15	.46	2.12	.083	.038	.033	.020	.037	.211
7	Ammonium sulfate in April, May, June, July, August, and September	4	24	1.30	.58	.47	.29	.61	3.25	.109	.050	.041	.028	.046	.274
8	10-6-4 in April, June, and August	8	24	1.08	.39	.40	.15	.36	2.38	.110	.051	.041	.021	.034	.257
11	Like 8 plus clippings	8	24	1.53	.57	.66	.18	.55	3.49	.168	.065	.074	.026	.055	.388
	Average	....	....	1.04	.38	.36	.16	.35	2.28	.099	.043	.040	.021	.032	.235

TABLE 7.—Nutrient elements removed month by month by Kentucky bluegrass—continued

Plot	Treatment			Fertility elements in grass per 1,000 sq. ft.						Recovery of added elements		
	Material	Per 1,000 sq. ft.		Potassium								
		Per application	Per yr.	May	June	July	August	September	Total	Nitrogen	Phosphorus	Potassium
		Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Pct.	Pct.	Pct.
1	Nothing	....	....	0.243	0.102	0.126	0.058	0.080	0.609	....	....	....
3	Ammonium sulfate in April	4	4	.348	.119	.136	.074	.080	.757	57	....	....
5	Ammonium sulfate in April	12	12	.616	.181	.132	.058	.068	1.055	58	....	....
6	Ammonium sulfate in April, June, and August	4	12	.470	.194	.188	.082	.154	1.088	48	....	....
7	Ammonium sulfate in April, May, June, July, August, and September	4	24	.612	.288	.192	.133	.221	1.446	47	....	....
8	10-6-4 in April, June, and August	8	24	.588	.269	.206	.086	.144	1.293	60	20	142
11	Like 8 plus clippings	8	24	.877	.347	.374	.100	.240	1.938	106	41	277
	Average	....	....	.536	.214	.193	.084	.141	1.169	....	....	....

Inorganic and organic carriers of nitrogen.—With mixed fertilizers, even of the same analysis, however, the results obtained may be very different because of the variability in the materials, particularly the nitrogen carriers, of which the mixture was compounded. If, for example, all the nitrogen is supplied in a highly soluble chemical like ammonium sulfate, the effect obtained is prompt but of short duration. Grass thus stimulated into rapid growth is comparatively soft and lush and relatively susceptible to adverse climatic and soil conditions. If the nitrogen is supplied in a variety of carriers including not only inorganic but also organic materials, a less marked initial, but a more prolonged, effect may be expected. Relatively slow-growing grass is comparatively sturdy and quite resistant to disease and other unfavorable conditions.

That an appreciable difference in the response of grass may result from the source of the nitrogen used was shown in a lawn fertility test including 13 nitrogen carriers. In this test the various plots consisted of four sections, each 5 by 10 feet, arranged end to end with an aisle 1 foot wide between sections. The plots as a whole were separated from each other by aisles 2 feet wide.

The plots were seeded August 15, 1928, with a mixture of Kentucky bluegrass, redtop, and perennial ryegrass in the proportion of 60, 20, and 20 per cent, respectively. The mixture was seeded at the rate of 5 pounds per 1,000 square feet. The aisles between plots were seeded with Chewings fescue. No fertilizer of any kind was applied at the time of seeding, and a fairly good stand of grass was obtained.

The fertilizer applications were started in the spring of 1929. Each year they were made three times, usually in April, June, and August. Each carrier was applied in quantities that would supply nitrogen at the rates of 2.5, 5.0, and 7.5 pounds per 1,000 square feet per year. The fourth section of each plot served as a check. The applications were continued through 4 years, 1929-1932, inclusive. After that, they were discontinued.

The grass was mowed often enough to maintain good lawn conditions. The kind and quantity of nitrogen carriers used and the 4-year average yield and increase of fresh grass were as shown in table 8. In this table the carriers are grouped as inorganic and organic. The inorganic group consists of two subdivisions, one carrying nitrogen alone, the other carrying considerable quantities of either phosphorus or both phosphorus and potassium in addition to nitrogen.

The quality of turf produced was quite accurately reflected by the quantity of grass obtained. During the active years of the test, the general appearance of the plots was rather in favor of those which had received the inorganic carriers. During the earlier years of the period of neglect, however, the aftereffect of the fertilizers persisted longer on the plots that had received organic than on those which had received inorganic carriers.

The quantity of grass on all the plots receiving inorganic nitrogen was greater than on the ones receiving organic nitrogen. As might be expected, the subgroup carrying fertility in addition to nitrogen gave somewhat more growth than did the one carrying nitrogen alone.

The increase in growth from each of the three increments of nitrogen was practically the same in the group of organic carriers, but in the groups of inorganic carriers it was markedly less from the third than from the second or the first. This difference may be regarded as indirect evidence that the inorganic carriers give up their nitrogen more readily than do the organic.

TABLE 8.—Effect from inorganic and organic carriers

Applied in equivalent quantities and each at rates of 2.5, 5.0, and 7.5 pounds of nitrogen per 1,000 square feet per year

Kind of fertilizer	Green weight per 1,000 sq. ft. (4-yr. av.)									
	Actual				Increase			Gain from each increment		
	0 Lb.	2.5 Lb.	5.0 Lb.	7.5 Lb.	2.5 Lb.	5.0 Lb.	7.5 Lb.	2.5 over 0 Lb.	5.0 over 2.5 Lb.	7.5 over 5.0 Lb.
Inorganic										
Ammonium sulfate	198	368	546	619	170	348	421	170	178	73
Calcium nitrate	150	328	531	636	178	381	486	178	203	105
Sodium nitrate	142	377	578	626	235	436	484	235	201	48
Leunasalpeter	144	302	481	624	158	337	480	158	179	143
Average	158	344	534	626	185	375	468	185	190	92
16.5-20-0 (Ammo Phos)	173	381	530	621	208	357	448	208	149	91
15-30-15 (Nitrophoska)	161	348	595	685	187	434	524	187	247	90
15-30-15 (homemade)	155	367	568	664	212	413	509	212	201	96
10-6-4 (homemade)	177	349	565	679	172	388	502	172	216	114
Average	166	361	564	662	195	398	496	195	203	98
Organic										
Calurea	146	273	392	491	127	246	345	127	119	99
Urea	153	276	380	457	123	227	304	123	104	77
Milorganite	116	223	353	487	107	237	371	107	130	134
Cottonseed meal	121	263	407	576	142	286	455	142	144	169
Soybean meal	140	253	426	557	113	286	417	113	173	131
Average	135	258	392	514	122	256	378	122	134	122

Positive evidence that the organic carriers give up nitrogen at a slower rate of speed than do the inorganic ones is shown by the percentage of nitrogen found in the fresh sap of the green grass. Material for these determinations was collected at each mowing throughout the season of 1931. Samples were collected from the plots fertilized with each carrier at the heaviest rate, 7.5 pounds of nitrogen per 1,000 square feet, also from the corresponding check for each. The samples were transferred immediately to the laboratory and ground finely with a food chopper. The sap was expressed as described by Sayre and Morris (11), with a pressure of 5,000 pounds per square inch. In this sap the nitrate and ammonia nitrogen were determined. The content of nitrogen in the sap did not differ markedly with the various carriers of either the inorganic or the organic group, but between the two groups the content was significantly higher with the former than with the latter throughout the season. With the exception of a short period in midsummer, the contents were both decidedly higher than those of the checks. These differences expressed as percentages are shown graphically in figure 7. From the graph it can be noted that a marked rise in nitrogen content of the sap followed each application of fertilizer.

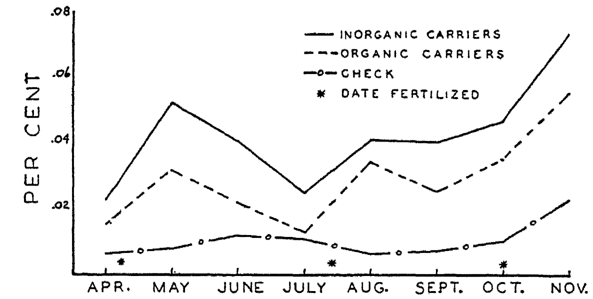

Fig. 7.—Nitrogen in sap of green grass fertilized with inorganic and organic carriers of nitrogen and unfertilized

*Fertilizer applied April 21, July 29, and October 15

The intake of nitrogen affected markedly both the quantity and quality of grass. The quantity of green grass produced, shown graphically in figure 8, was not markedly different in the two groups. In both, however, it was

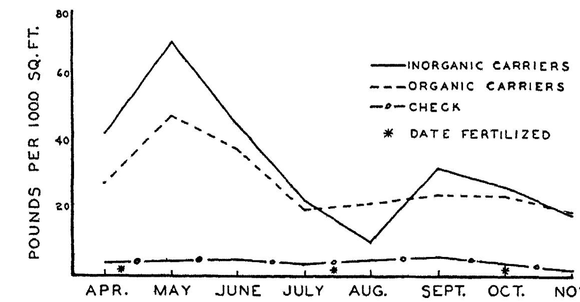

Fig. 8.—Yield of grass (green weight), 1931

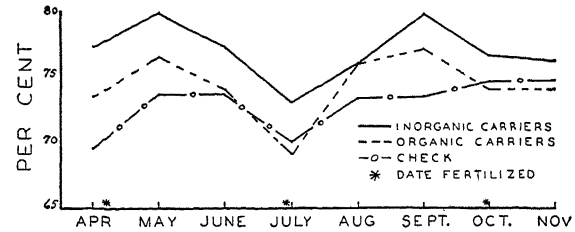

Fig. 9.—Moisture content of grass, 1931

decidedly higher than in the checks in the early part of the season and somewhat higher in the fall. In a dry period in late July and August, the growth and general appearance of the grass on the plots fertilized with the organic carriers were superior to those on the plots top-dressed with inorganic carriers. As might be expected, both classes of fertilizer produced lushness of growth, as is indicated by the relative moisture content of the grass, shown graphically in figure 9.

CULTURAL PRACTICES

Although plots 8 to 14 inclusive (table 4) received the same kind and quantity of fertilizer, each was handled differently, as is indicated in the table. In this group, plot 8 can be regarded as a standard or check. With the exception of the plot to which the clippings were returned, no important differences in general appearance became apparent before the test was terminated. From the yields obtained during the active years of the test, however, slight trends were indicated in most cases.

Compost.—Top-dressing with a light layer of compost each fall had little or no effect on the growth of grass, as can be seen from table 4. As contrasted with that on plot 8, the growth on plot 10 was approximately 114, 108, 99, 97, and 107 per cent in 1928, 1929, 1930, 1931, and 1932, respectively. The evidence is, of course, not conclusive, but each application was light and the period through which it was continued was relatively short.

Return of clippings.—The results obtained from allowing the clippings to remain on the lawn were decidedly positive. Not only was the growth of grass increased, as shown in figure 10, but the shade of green was also greatly intensified. In the drouth year of 1930 and after, however, these effects were less marked.

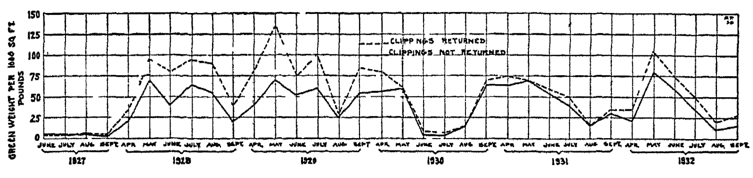

Fig. 10.—Return of clippings promotes the growth of grass.

In an earlier test, started August 14, 1925, and located on somewhat poorer soil, the grass on the plot where the clippings were returned was also darker green in color, particularly in the dry period of summer. The increase in growth from this plot amounted to approximately 14, 40, 58, and 76 per cent over the plots to which clippings were not returned for the years 1926, 1927, 1928, and 1929, respectively.

These two tests indicate clearly that the return of clippings is beneficial, at least to new seedings in the early years of their establishment. Whether the indefinite continuance of this practice is advisable may be open to question. In any event, if clippings are returned, the mowings should be made with such frequency that the refuse will disappear readily; otherwise the dried clippings will become unsightly and may smother the grass through matting. If a moldy condition develops, as it often does in shady places, particularly in wet weather, the clippings should be removed.

Frequent mowing.—In general, regular mowings were made approximately a week apart except in the hot dry weather of midsummer, when they were less frequent. The time for mowing was determined by the growth of the grass. On plot 12, table 4, which was mowed twice the normal frequency, the growth as compared with that on plot 8 was 102, 89, 92, 84, and 87 per cent in 1928, 1929, 1930, 1931, and 1932, respectively. These results hardly sustain the idea that frequent mowing benefits grass. Frequent mowing does, however, make for neatness, especially if many weeds are present.

Late mowing.—In a test on late mowing, plot 13, table 4, the last mowing was made November 1, November 5, November 15, November 15, and November 4 in 1928, 1929, 1930, 1931, and 1932, respectively. These dates were from 4 to 6 weeks later than those on which the regular mowings had been discontinued. From both plots the clippings were removed. As compared with plot 8, the growth constituted 107, 89, 82, 80, and 88 per cent in 1928, 1929, 1930, 1931, and 1932, respectively. The consistently lower yield, though the difference was small, could hardly be attributed to any inferiority of the plot, for at the beginning, 1928, the yield on it was practically the same as on plot 8.

In an earlier test of this kind, the clippings were returned. This comparison was started August 14, 1925, but the plots were not clipped that fall. In succeeding years the late-cut plots were last mowed November 2, 1926, November 4, 1927, and November 1, 1928. The last cutting on the check was made September 21, 1926, September 29, 1927, and September 12, 1928. The growth on the late-cut plots as compared with the check amounted to 86, 85, and 90 per cent in 1927, 1928, and 1929, respectively. From both these tests the indications are that late mowing is not a good maintenance practice. Leaving considerable growth in the fall, however, may result in unusual burrowing by moles. Moreover, refuse of this kind, unless mowed early in the spring, obscures the first new growth and thus delays appreciably the return of the "greening-up" after the winter. If tidiness in the late fall is of paramount importance, then late cutting should be accompanied by a little more liberal fertilization than would otherwise be used.

Height of mowing.—In order to ascertain the most desirable height at which to cut grass, from the standpoint of both appearance and maintenance, a test was started in 1935 in which the grass was mowed at four different levels, ½ inch, 1 inch, 1½ inches, and 2 inches. The areas mowed were 5 by 70 feet and paralleled each other. Each of the 4 strips extended across an old series of 11 fertility plots which had been abandoned. With a few exceptions in the first year, 1935, the mowings were made at approximately weekly intervals from May 1 to October 2 inclusive.

So far as the beauty of the grass was concerned, it decreased as the height of mowing increased, largely because of the presence of weeds. The leaves of weeds like the plantains and dandelions are relatively broad and long as compared with those of most turf grasses and unless cut close may detract materially from the neatness and tidiness of a turf. If a lawn is practically free of weeds, its attractiveness suffers little, if any, from high mowing.

From the standpoint of maintenance it would seem that low mowing would be detrimental because of the reduction in leaf area and hence in photosynthetic activity. During the 3 years of this test, however, this assumption was not borne out, at least not by the growth made above ground. The yields were as shown in table 9.

TABLE 9.—Effect of height of cutting on growth of grass

Height of clipping	Growth of green grass per 1,000 sq. ft.							
	Actual				Relative*			
	1935	1936	1937	3-yr. av.	1935	1936	1937	3-yr. av.
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
½ in.	286	268	275	276	217	344	237	253
1 in.	221	175	237	211	167	224	204	194
1½ in.	166	117	183	155	126	150	158	142
2 in.	132	78	116	109	100	100	100	100

*The yield from cutting the grass 2 in. high is regarded as 100.

In each season the yields became progressively higher as the level of mowing was lowered. The ½-inch mowings yielded two to three times as much as did the 2-inch ones. Undoubtedly, these differences were somewhat accentuated by crabgrass. That low mowing favors the growth of crabgrass is indicated by the relative number of crabgrass plants found on these plots. At the close of each mowing season the number was counted. The 3-year average number expressed in terms of plants per 1,000 square feet was 7,410, 6,736, 4,054, and 2,044 on the areas clipped ½ inch, 1 inch, 1½ inches, and 2 inches, respectively.

Paradoxical as it may seem, the relative weight of roots in the high and low mowing areas was the reverse of that of the grass. Following the completion of each season's mowings, a series of 11 soil samples was taken to a depth of 10 inches from the area mowed one-half inch high, and a second series from the area mowed 2 inches high. The group of 11 samples in both series consisted of one taken from each of the 11 original fertility plots. It was thus possible to make 11 comparisons from strictly comparable soil so far as previous treatment was concerned.

The samples were obtained by means of a cylinder 2 inches in internal diameter, similar in principle to the sampling apparatus described by Evans (4). After the root material was carefully washed out of the soil, the roots were dried and ashed at low red heat in accordance with the method suggested by McCall (8).

The weight of roots obtained shows that the high mowing resulted in a greater root growth than did the low mowing on each of the 11 plots in each of the 3 years 1935, 1936, and 1937. When the 11 determinations were averaged and the results were expressed in terms of pounds per 1,000 square feet (oven-dry), the returns from high and from low mowing were, respectively, 86 and 63 pounds in 1935, 187 and 89 pounds in 1936, and 129 and 54 pounds in 1937.

In other words, the roots in the low mowing amounted to approximately 73 per cent of those in the high mowing in 1935, 48 per cent in 1936, and 42 per cent in 1937.

In view of these and of similar results reported by Harrison (6), the yields recorded in table 9 are difficult to explain, for one would naturally expect a depletion in growth under ground to result in a similar depletion in growth above ground. Presumably a continuation of high and low mowing would result eventually in a reversal of the relative yield. In this connection it is of interest to note the results reported by Graber (5). In mowing Kentucky bluegrass ½ inch high and 1½ inches high, he obtained more grass from the low mowing the first year. In the second season, however, he obtained less grass from the low than from the high mowing and five to seven times as many weeds, particularly dandelions.

Rolling.—All the plots in the maintenance series (table 4) except No. 14 were rolled once a year in March after the ground had thawed but before it had become settled. The growth of grass on plot 14 as contrasted with that on plot 8 was 111, 90, 82, 86, and 97 per cent in 1928, 1929, 1930, 1931, and 1932, respectively. Although these differences were not large, they indicate that over a long period of years, failure to roll the lawn might be an important factor in bringing about its gradual deterioration. Theoretically, an annual rolling made under favorable conditions should be helpful. The freezing and thawing of winter lift the soil and leave the surface loose and uneven. Rolling not only firms the ground around the grass roots and thus prevents unnecessary drying out of plants, but it also levels the surface and thus facilitates mowing at a uniformly even height as contrasted with the promiscuous "scalping" which is unavoidable in clipping an uneven surface.

The weight of roller and amount of rolling should vary with the type of soil. Clay soils will require less than sandy ones. On clay, the weight should be no greater than necessary to smooth the surface. With a water-filled roller the weight can be adjusted to suit conditions. Such a roller 1½ feet in diameter and 2 feet in length, outside measurement, holds approximately 25 gallons and when filled with water weighs about 275 pounds. A roller of this kind filled to capacity should give good results on a sandy soil, but on those of a heavier type the quantity of water should be reduced somewhat. Not more than one rolling is advisable.

Mulch.—On an established lawn, four plots each containing 100 square feet were covered, two with maple and two with oak leaves, the two kinds alternating. The leaves were spread loosely to a depth of approximately 4 inches, covered with woven wire, and weighted to hold them in place. The test was continued through 4 years. Fresh sets of leaves were used each year, but the same kind was always put on the same plot. The leaves were spread at approximately the same time each fall, from November 30 to December 9, and were removed with the coming of warm weather in the spring, from March 31 to April 9.

The results of the continued mulching were decidedly detrimental. After the third year, the thinning of the grass and the coming in of weeds, particularly narrow-leaved plantain, were clearly perceptible. After the fourth year the condition of the mulched area was not hopeless, but the appearance was such that it would not have been selected as a show place. No difference related to kind of leaves was noticeable.

Beginning in 1927 and continuing each year thereafter, one-half of each of the newly seeded plots in the time-of-seeding test was mulched with maple leaves in the same manner as the established lawn. In this test the date of covering ranged from November 30 to December 28; the time of removal was the same as on the established lawn. Each year the mulched portion of all the plots, regardless of date of seeding, was perceptibly inferior to the unmulched.

A new seeding consisting of a Kentucky bluegrass - redtop mixture made September 7, 1934, was mulched January 2, 1935. One-third was mulched with peat to a depth of approximately one-fourth inch; one-third, with well-shaken wheat straw in such quantity as merely to cover the surface nicely. In the spring of 1935 the straw was removed. The mulched grass showed improvement over the unmulched, but there was no perceptible difference between the two materials. On a new seeding, peat is difficult to hold in place, as it is easily blown away by the wind. For reasons already mentioned, straw is hazardous to use unless it is first thoroughly shaken.

Watering.—An experiment in watering was started in 1927 for the purpose of noting the effect of rate, frequency, and time of application. Detailed reports of the effect of varying quantities of water and a suggested method, based on the use of an evaporation index, for determining optimum amounts have already been published (13, 14, and 15), and hence a detailed summary will not be repeated here. In these tests a quantity of water equivalent to twice the normal rainfall proved to be ample in all years, and the period covered included some very dry summers. The use of more than two times the normal was positively injurious. In two relatively dry seasons, 1932 and 1934, when the rainfall (May to August inclusive) was approximately 69 and 77 per cent, respectively, of the normal, from 8,000 to 10,000 gallons of water per 1,000 square feet in addition to the rainfall were required to maintain the grass in a thrifty condition. From these results it can be seen that the cost of water alone might be an item of considerable expense if weather conditions were such as to make watering desirable throughout the season. Before starting to water, a lawnowner should resolve to continue, if necessary, at timely intervals during the period of scarcity, for sporadic watering is of little value and may be positively harmful. Continued watering resulted in the encouragement of some other species, particularly velvet grass (*Holcus lanatus*), crabgrass (*Syntherisma sanguinale*), and white clover (*Trifolium repens*).

The outcome of the comparisons between daily and weekly and between morning and evening applications was negative. No appreciable differences could be observed. Both these comparisons, however, were made on the basis of two times the normal rainfall. Inasmuch as a concurrent test demonstrated that this quantity was ample under all conditions, it is felt that the use of smaller amounts in these two comparisons might have resulted in specific differences. It should perhaps be added that time of watering may be a factor in the control of certain turf diseases, for Dahl (2) found less brown patch on bent grass on a putting green watered in the morning than on one watered in the evening.

RAINFALL IN RELATION TO GROWTH

Growth of grass is not dependent on soil fertility alone. That there is a close relationship between growth and moisture is indicated by the correlation between rainfall and growth in the seasons 1929-1932 inclusive, shown in figure

11. The yields were based on the average of the Kentucky bluegrass sections of the 14 maintenance plots, and the rainfall represents the period March 15 to September 15 inclusive of each year.

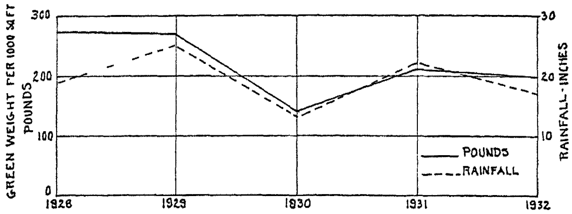

Fig. 11.—Influence of rainfall on growth of grass

SPECIES OF GRASS

According to Schaffner (12) there are in Ohio about 180 species of grass (including cereals and those grown for other special purposes). On account of the many requirements for good turf, however, the number suitable for lawns is restricted to a relative few. All grasses have fibrous roots but many do not develop creeping rootstocks, which, together with the roots, are what constitute sod. Not all sod-forming grasses make good turf. The character of turf depends largely on the habit and extent of growth of the rootstocks and the vigor with which they develop. Some produce a smooth, even surface; others, one that is rough and bunchy. Enduring turf grass must be able to persist under highly artificial conditions, for the relatively close mowing to which lawn areas are subjected is abnormal and intensifies greatly the adverse conditions under which the grass is required constantly to recuperate. The leaves are the factory in which the food is manufactured, and if these are largely removed and the leaf area thus greatly restricted, the work they can do is much impaired. A good turf-forming grass, therefore, not only should be leafy but should also have leaves that develop close to the ground so that as many as possible may remain after mowing. From the aesthetic point of view, the leaves should be reasonably fine and possess a pleasing shade of green.

Resistance to drouth, shade, disease, animal and insect pests must not be overlooked, and finally, and perhaps most important of all, a successful turf grass must be adapted to its environmental conditions, both the soil and the climate.

The more common grasses.—With these restrictions in mind, 32 kinds of grass representing 12 genera were seeded in order to study and observe their behavior under lawn conditions. Carpet grass (*Axonopus compressus*), crested dogstail (*Cynosurus cristatus*), sweet vernal grass (*Anthoxanthum odoratum*), and Bermuda grass (*Cynodon dactylon*) apparently were unadapted, for they soon died. Bermuda grass did not go through a single winter. Other grasses, such as brome grass (*Bromus inermis*), and tall oat grass (*Arrhenatherum elatius*) were too coarse. Numerous others, like orchard grass (*Dactylis glomerata*) and sheep's fescue (*Festuca ovina*), were not only coarse but bunchy. Certain others, like Canada bluegrass (*Poa compressa*), were unattractive because of lack of leafiness. A few like fine-leaved fescue (*Festuca ovina tenuifolia*) became patchy and unsightly because of excessive but uneven browning in the hot dry weather of midsummer. On account of complete failure of some and admixtures of others, many of the plots after 5 years became unsatisfactory from an experimental standpoint and were plowed up. So far as can be judged from this test, all grasses of permanent worth for lawn purposes in this section are found in three genera, *Poa*, *Agrostis*, and *Festuca*, and in each of these the number of acceptable species is limited to a few.

Of the relatively small number of grasses acceptable, none is entirely satisfactory, but undoubtedly the one held in highest esteem by the greatest number of people is Kentucky bluegrass (*Poa pratensis*). It is almost universally adapted to Ohio soil and climatic conditions and thus with reasonable attention may be expected to persist not 5 years or 10 years but indefinitely. In the species test to which reference has already been made, most of the admixture, as far as grasses were concerned, was due to the coming in of Kentucky bluegrass. An adaptability as good as or better than that of the ones displaced is therefore indicated. Further proof of its adaptation and evidence also of its ability to persist without special care are afforded by its distribution throughout Ohio pastures. Furthermore, the shade of green possessed by its leaves is unsurpassed.

In starting a lawn of Kentucky bluegrass the seed should be mixed with some more rapidly growing sort like redtop in order to give a green cover quickly and to help check weed growth and possible erosion. A good all-round mixture for ordinary conditions where no special care in subsequent years is intended is:

12 pounds of Kentucky bluegrass
4 pounds of redtop
1 pound of white clover

The clover may or may not be included; that is largely a matter of choice. If the owner does not expect to give much care to the lawn, it is advisable to add the clover, because being a legume, it will help to keep up the fertility of the soil.

One weakness of a Kentucky bluegrass lawn is that it becomes more or less dormant for a considerable period in the summer if the weather is dry and hot. To ascertain whether a more uniformly even and pleasing effect throughout the season could be obtained by mixing with Kentucky bluegrass some other permanent grass or grasses like the colonial bents or Chewings fescue and to note at the same time the behavior of temporary grasses other than redtop, like the ryegrasses and timothy, two series of mixtures were started, one August 15, 1928, and one September 12, 1932. The accompanying permanent grasses enhanced in a measure the fineness of texture in the early stages. The fescue inhibited somewhat the coming in of crabgrass. On the other hand, the fescues are rather hard to mow, and the viability of the seed after it reaches this country from New Zealand is often low. The shade of green of the colonial bent is somewhat dissimilar to that of Kentucky bluegrass, and when they are mixed, therefore, the effect is not all that could be desired. Furthermore, after the first fall frost, the bents take on a rather unsightly brownish color, and this unfortunate appearance persists the following spring long after Kentucky bluegrass has assumed its distinguishing shade of green.

On poor, sandy, and somewhat acid soils, Kentucky bluegrass does not thrive as well as some other grasses. On such soils a more suitable mixture than the one already mentioned would be one something like the following:

12 pounds of Chewings fescue
4 pounds of Canadian bluegrass
5 pounds of redtop

The inclusion of one or more species of ryegrass in addition to redtop is desirable where it is important to get a cover and to fill the ground with roots quickly, because the ryegrasses grow even more rapidly than redtop. Italian ryegrass is preferable to perennial not only because it grows more rapidly but also because the latter remains for more than 1 year and persists in sending up seed stalks which are more or less unsightly. Timothy also comes up quickly, but aside from cheapness of seed it has no special merit.

Creeping bent.—For persons who can devote a great deal of time, attention, and money to the maintenance of a lawn, the use of creeping bent is admissible, for with proper care, a turf of pleasing ruglike appearance and great beauty can be developed, as shown in figure 12 (top). Metropolitan, Virginia, and Washington strains were started in plots on October 11, 1927. The Metropolitan and Washington strains are among the most popular, and both make a comparatively dense turf. The Metropolitan is a little coarser than the Washington, but this coarseness is perhaps more than offset by the richness of its dark green color. The Virginia is unattractive in color and develops a comparatively thin turf. It is also less resistant than the others to adverse conditions, (figures 12, bottom, 13). To maintain a creeping bent lawn requires much

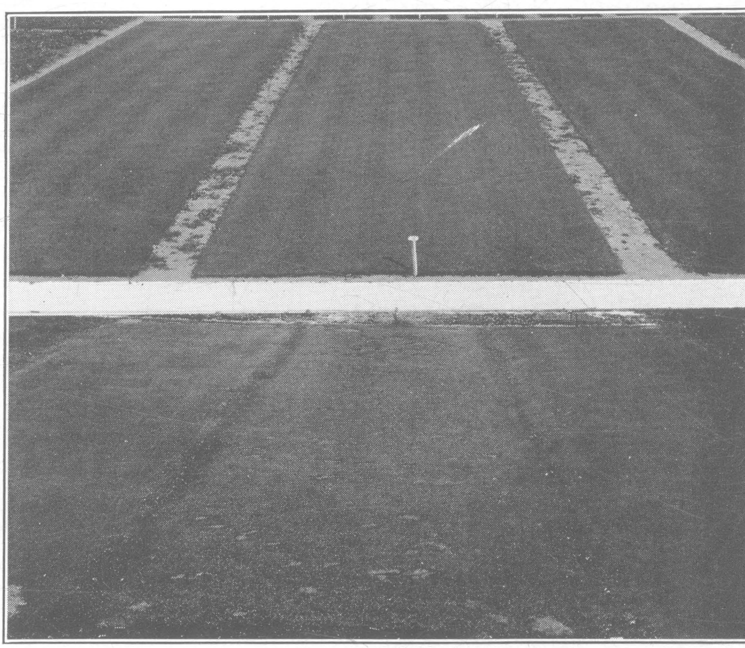

Fig. 12.—Creeping bent

Top—Metropolitan (left), Virginia (middle), and Washington (right). Photographed September 11, 1929

Bottom—Metropolitan (right), Virginia (middle), and Washington (left). Photographed October 2, 1931 care, close and sometimes daily mowing, frequent and liberal fertilization, profuse watering, occasional composting, and treatment for various diseases, principally brown patch, which in some years occurs frequently. Moreover, the so-called short-winged or hairy chinch bugs (*Blissus hirtus*) sometimes infest creeping bent. Even though creeping bent may have become well established, it cannot be long neglected, for it deteriorates rapidly with the kind of care ordinarily accorded a lawn. Under neglect, creeping bent soon dies out in patches, is replaced in part by other grasses, and becomes unsightly in general, as shown in figure 13.

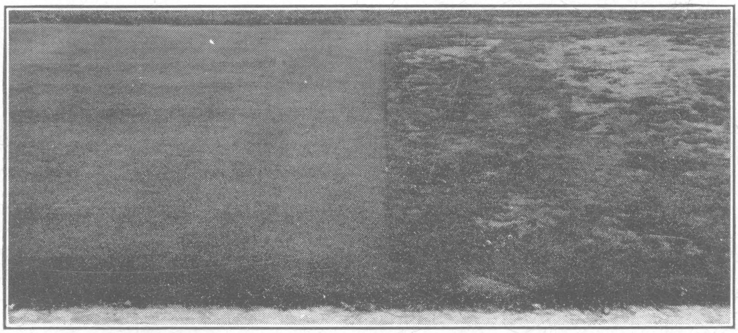

Fig. 13.—With ordinary care (right) creeping bent is a disappointment.

In 1930, 1931, and 1932, a record was kept of the quantity of nitrogen added to and removed from soil on which three strains of creeping bent were grown. The nitrogen was applied in the form of ammonium sulfate at 2-week intervals from March 18 to September 16 at the rate per 1,000 square feet of 4 pounds in March, April, and May; 3 pounds in June and September; and 2 pounds in July and August. Samples from the almost daily clippings were grouped for each month, and on the composites thus formed, nitrogen determinations were made. As shown in table 10, the nitrogen content did not vary materially between strains of bent or times of year, and but little from year to year. It was somewhat higher in 1931, the year following the severe drouth.

In table 11 are given for each strain of bent the green and dry weight, the percentage of nitrogen, the total nitrogen removed in clippings, the quantity of nitrogen applied in the form of ammonium sulfate, and the percentage recovery of added nitrogen. The quantity of nitrogen per 1,000 square feet in the clippings from Metropolitan, Virginia, and Washington was 4.6, 5.7, and 4.8 pounds, respectively, or 4.2, 3.1, and 4.0 pounds, respectively, less than the 8.8 pounds applied to each in the form of ammonium sulfate.

A 10-6-4 fertilizer gave much better results on bent grass than did ammonium sulfate alone in tests on the maintenance series, the bent section of which was re-established in the spring of 1932. A year after re-establishment, sections of turf typical of that fertilized with ammonium sulfate and that fertilized with 10-6-4 appeared as shown in figure 14. These plots had been systematically fertilized since 1927.

TABLE 10.—Nitrogen content month by month of three strains of creeping bent

Month	1930				1931				1932			
	Metropolitan	Virginia	Washington	Av.	Metropolitan	Virginia	Washington	Av.	Metropolitan	Virginia	Washington	Av.
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
April	5.31	5.09	4.97	5.12	4.08	5.06	4.94	4.69	3.78	4.27	3.72	3.92
May	5.13	4.95	5.23	5.10	4.89	4.80	4.83	4.84	4.13	4.31	4.30	4.25
June	4.48	3.93	3.98	4.13	5.17	5.15	5.39	5.24	4.19	4.24	3.57	4.00
July	3.85	4.52	4.04	4.14	4.78	5.04	4.89	4.90	4.35	4.81	5.01	4.72
August	4.28	4.60	4.20	4.36	5.18	5.05	4.94	5.06	4.96	4.96	5.22	5.05
September	5.19	4.58	4.28	4.68	5.79	5.15	5.81	5.58	5.49	4.86	5.04	5.13
October					5.45	5.08	5.04	5.19	5.45	5.08	5.04	5.19
Average	4.71	4.61	4.45	4.59	5.05	5.05	5.12	5.07	4.34	4.65	4.56	4.52

TABLE 11.—Growth of creeping bent per 1,000 square feet and nitrogen removed, 3-year average

Strain of creeping bent	Green weight	Dry weight	Nitrogen	Nitrogen removed in clippings	Nitrogen applied in form of ammonium sulfate	Excess of nitrogen applied over that removed in clippings
	Lb.	*Lb.*	*Pct.*	*Lb.*	*Lb.*	
Metropolitan	358	97	4.70	4.6	8.8	4.2
Virginia	426	119	4.77	5.7	8.8	3.1
Washington	369	102	4.71	4.8	8.8	4.0

SHADY PLACES

Probably one of the most difficult problems with which a lawnowner has to deal is that of establishing and maintaining grass under trees and in other shady places. Under trees there is a curtailment of light, and the shallow root system of grass is forced into competition for moisture and soil nutrients with the well-established and relatively deep root system of the trees. Shallow-rooted trees like the various species of maples and willows offer more competition than do moderately deep-rooted ones like elms or tap-rooted sorts like the oaks and nut trees. Copious supplies of water are taken up by trees and transpired through the leaves. Much of the rainfall that would otherwise naturally fall on the ground is dissipated through evaporation from the extensive leaf area of the trees, and much of that which eventually does find its way to the ground arrives in the form of a stream down the tree trunks and is, therefore, not well distributed.

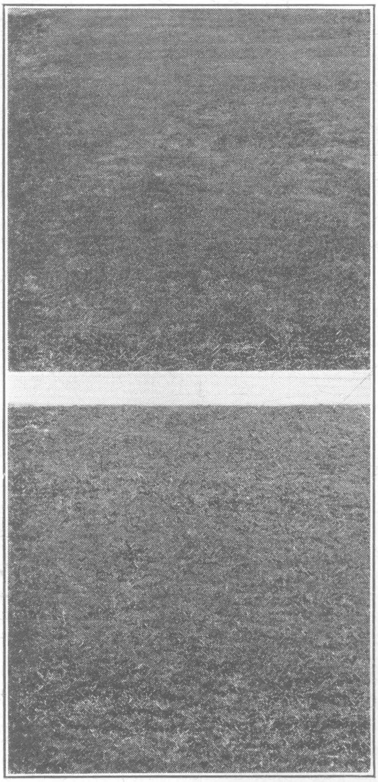

Fig. 14.—Creeping bent

Top—Complete fertilizer—nitrogen, phosphorus, and potassium

Bottom—Incomplete fertilizer—nitrogen only

There is a difference among grasses in their reaction to these adverse conditions. In order to observe the performance of some of them in such situations, a test was started in 1927 in which were included those grasses reported to possess more or less tolerance to these conditions. In this test each kind of seed was sown on the south side of a different hard maple tree. These trees were approximately 35 years old and the trunks were from 12 to 14 inches in diameter. The conditions thus afforded were not ideal from the standpoint of a good shading test, because, being on the south side of the trees, the plots received considerable direct sunlight. They did, however, provide an opportunity to note the effect of unfavorable factors incident to tree growth other than partial lack of light.

In this test, Chewings fescue (*Festuca rubra fallax*), proved most satisfactory. Seed of this variety is imported from New Zealand. Presumably, an important factor contributing to its success is a seemingly low water requirement. That Chewings fescue can get along with less water than Kentucky bluegrass (*Poa pratensis*), for example, was indicated indirectly. In 1929 and 1931, years of about normal rainfall, the growth made by each was about the same, but in the extremely dry year of 1930, Chewings fescue was affected adversely less than Kentucky bluegrass, as shown in figure 15. Probably another reason why Chewings fescue can survive dry years and shady conditions under trees better than Kentucky bluegrass is that the fescue has a more elaborate root system with which to take up water. Roots washed from soil samples taken from five plots of each kind of grass to a depth of 8 inches showed an average gain of Chewings fescue over Kentucky bluegrass of 32 per cent. Moreover, the roots of the fescue apparently penetrate more deeply than do those of Kentucky bluegrass, for in this test it was found that in the fourth 2-inch zone, the quantity of roots was approximately 93 per cent greater for the fescue than for the Kentucky bluegrass. Further evidence of the comparative growth of the roots of these two grasses is shown in figure 16. Each pile represents the total root material washed from five 1-gallon jars; the larger one is the roots of Chewings fescue.

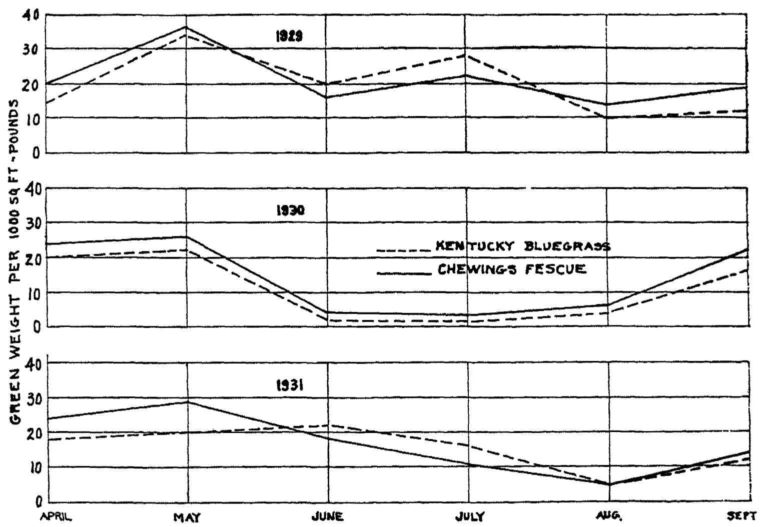

Fig. 15.—In a dry year like 1930 Chewings fescue suffers less than does Kentucky bluegrass

The field seeding of Chewings fescue made in 1927 was not yet extinct in 1939. The condition of the turf at present is not perfect, but the unfavorable condition is in part attributable to an outbreak of sod webworms in 1931. In that attack the pest showed a marked preference for certain grasses, and among those, apparently its first choice was Chewings fescue.

From the standpoint of beauty, rough-stalked meadow grass (*Poa trivialis*) is preferable to Chewings fescue, for the pleasing effect of its apple-green foliage is difficult to surpass. From the viewpoint of endurance, however, it has been far inferior to Chewings fescue. During the period of this test, 1927-1932, it has been necessary to reseed four times, and the grass of the last seeding, made in the fall of 1932, practically all died in the summer of 1933.

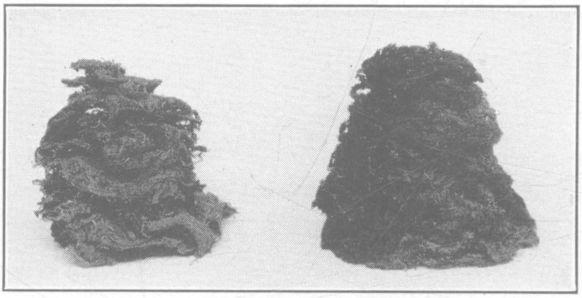

Fig. 16.—Comparative root growth of Kentucky bluegrass (left) and Chewings fescue

Both rough-stalked meadow grass and Chewings fescue have been tried in the city of Wooster on many shaded lawns and parking places. Apparently, in many of these areas conditions were too adverse for any kind of grass to endure, but in a few, satisfactory results were obtained with Chewings fescue. In one lawn, for example, which was practically bare, seed of rough-stalked meadow grass and Chewings fescue was sown on opposite sides of a walk in the spring of 1926. The original seeding of Chewings fescue is still standing, but it was necessary to reseed the rough-stalked meadow grass every year.

In one of these city lawn tests, Chewings fescue failed repeatedly several years in succession. Finally, a new spring seeding was not cut during its first season and it succeeded. In the two following summers also the grass was not cut and it endured. In 1934, 1935, and 1936, the lawn was mowed regularly but relatively high with fair results. More recently, most of the grass has disappeared.

Perhaps the chief reason for the inferior performance of rough-stalked meadow grass is its much less elaborate root system. Both grasses were grown in the same kind of soil in gallon jars in the greenhouse. After a few months the roots in three average jars of each class were washed out. The differences in volume are shown in figure 17. (The lower set is the roots of the rough-stalked meadow grass.) It is possible that this species may have considerable value on low, moist ground in heavy shade, inasmuch as seedings made under such conditions remained several years. That it is not altogether restricted to conditions of this kind is shown by its persistence for many years on certain heavy clay soils, as, for example, in several lawns in Oberlin, Ohio.

Wood meadow grass was included also in several tests both at the Experiment Station and in the City of Wooster, because it has a good reputation in Europe for growing in the shade. This grass was almost a complete failure in all cases.

In starting these grasses in old lawns under trees or in places otherwise shaded, the seed was sown on some quiet morning in March when the ground was honeycombed with frost, and subsequent freezing and thawing were depended on to cover the seed. If for any reason the ground does not honeycomb readily, the seed can be covered lightly by broadcasting over it some material like good garden loam or peat. In this way good stands have usually been obtained.

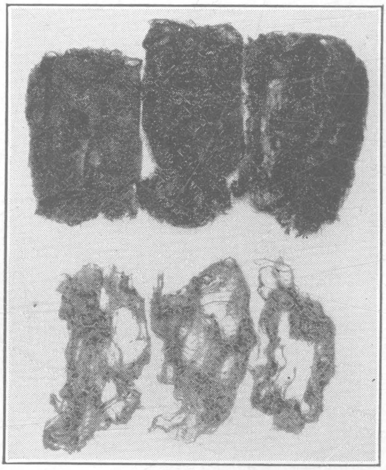

Fig. 17.—Comparative root growth of Chewings fescue (upper) and rough-stalked meadow grass

These tests indicate that where shade is a factor, the use of Chewings fescue in part or altogether is advisable. Where shade is partial but still dense enough to exert an adverse influence, a mixture like the following can be used:

14 pounds of Chewings fescue
4 pounds of Kentucky bluegrass
2 pounds of colonial bent

In heavily shaded areas, the fescue can be seeded alone at the rate of 8 to 10 pounds per 1,000 square feet. The amount suggested may be considered a heavy rate of seeding; nevertheless it is advisable, for the size of the seeds is large and by the time shipments reach this country from New Zealand the germination is often low. The poor germination appears to be related to the moisture content of the seed and to the temperature conditions under which the seed is stored (7). On account of the difference in time of seasons between New Zealand and the United States, new seed from New Zealand does not reach this country until early summer; hence, strictly fresh seed is never available for spring seedings. The success of a new seeding is made somewhat more likely by high mowing or even no mowing at all for the first year or two. Chewings fescue is a rather low-growing grass and in the unclipped condition, therefore, is not particularly unsightly.

In extremely shady places where all grasses fail, it is often possible to use some ground cover like Japanese spurge (*Pachysandra terminalis*). On April 3, 1929, 1,000 of these plants were set 6 by 6 inches on a bare area under and between two maple trees where the shade, intensified by adjoining trees, was very dense. A fairly good stand was secured, but the intense heat and drouth which occurred in the following years before the plants were well established resulted in the death of many of those close to the trunks of the trees. The remainder were still in a thrifty condition in 1939.

Myrtle, or common periwinkle (*Vinca minor*), also is very shade tolerant and frequently is used under trees and in other locations where on account of shade, grass does not succeed.

TERRACES

On steeply terraced areas, especially those with a south or west exposure, it is almost impossible to maintain a satisfactory turf, chiefly because of the difficulty of maintaining an adequate moisture supply. So far as the grasses are concerned, probably Chewings fescue or some similar grass is best adapted to such situations because its water requirement is relatively low.

In extreme cases, dwarf honeysuckle may be considered as a substitute for grass. It is more or less drouth resistant, can persist on poor soil, and is relatively winterhardy. In cold winters the leaves may become brown and remain thus late in the spring. A little pruning from time to time is about all the attention required

RENOVATION OF LAWNS

Means and methods for the improvement of lawns that have become weedy and unsatisfactory in general are contained in a subsequent bulletin.

SUMMARY

Weather records show that on the average, Ohio climatic conditions do not deviate greatly from the normal. Plants indigenous to the State rarely fail for climatic reasons alone.

Well-rotted stable manure proved more valuable than other material for use in establishing new lawns on subsoil brought to the surface in building operations. Cinders improved the physical condition of the soil more than sand, slag, surface soil, or coarse limestone. Liberal fertilization with a 10-6-4 on all the treated subsoil plots after the first winter resulted in the development of fairly satisfactory turf at the end of 3 years (including the year of establishment). Since the cessation of fertilization, the appearance of these plots has not remained satisfactory.

For the improvement of surface soil in a high state of fertility, well-rotted stable manure gave best results, but this material often introduces weeds. The addition of black soil was not helpful.

Time-of-seeding tests extending through 12 years indicated that on the average, late summer, August 20 to September 20, is the safest season in which to start a lawn. Seedings made later than September 20 did not become well rooted. If late summer seeding is impossible, seeding may be deferred until very late fall or very early spring. If the contour of the ground is such that it will not wash, the seeding can be made as soon as low temperatures can be depended on to prevent germination of seeds in the fall, usually November 10 or later. Midsummer seedings are unwise, but they can be made successfully if facilities are available with which to supply water artificially in hot dry weather. Winter seedings are sometimes, though not always, successful. If the seeds are well covered, the chances of success are materially improved.

The standard seed mixture (three parts by weight of Kentucky bluegrass, one part of redtop, and one-fourth of one part of white clover) was sown at 10 different rates ranging from 0.7 to 11.2 pounds per 1,000 square feet. In this test at least 3 pounds per 1,000 square feet were required to obtain a sward sufficiently dense to prevent the establishment of weeds.

The use of lime may or may not be helpful. Whether it will be depends on the reaction of the soil and the kind of grass desired. Kentucky bluegrass and white clover are at their best on alkaline, neutral, or only slightly acid soil. The fescues and bents tolerate a rather acid soil.

Steamed bone favors the development of good turf. Its action is slow, but its effect cumulative. It should be used with the idea of permanent benefit rather than immediate effect. Since this material has a neutralizing value of about 10 per cent, its use is commendable to maintain a sward of Kentucky bluegrass and white clover but not one of the bents or fescues.

Annual applications of ammonium sulfate made in the spring at the rate of 4 pounds per 1,000 square feet did not last through a single season. Better lawn appearance resulted from bimonthly and best from monthly applications.

A mixed fertilizer (10-6-4) gave as dense a stand and a better root system than ammonium sulfate.

Kentucky bluegrass contained on the average 3.37 per cent nitrogen, 0.38 per cent phosphorus, and 1.77 per cent potassium. It removed per 1,000 square feet during the period May through September, 2.28 pounds of nitrogen, 0.24 pound of phosphorus, and 1.17 pounds of potassium.

Inorganic carriers of nitrogen gave a more vigorous immediate but a less prolonged growth than organic carriers. Nitrogen appeared more quickly and in greater quantity in the sap of grass fertilized with inorganic than in that fertilized with organic carriers of nitrogen. The fertilization affected both the quantity and quality of grass produced.

A light application of compost each fall did not result in an appreciable gain in the appearance of the lawn.

Returning clippings to the lawn increased the growth and intensified the green color of the grass.

Frequent mowing of grass did not prove beneficial. Ordinarily, mowing is discontinued some time between September 15 and October 1. When mowed as late as November 1, the grass was less vigorous the following year. In a 3-year test, close mowing (one-half inch) contrasted with high mowing (2 inches) resulted in an increase in growth of grass, a decrease in root development, and an increase in stand of crabgrass.

One rolling of the lawn when the soil was in suitable condition in early spring was effective and beneficial.

Established lawn plots on which annual mulches of maple and oak leaves were placed in the fall showed injury in the fourth year. New fall seedings mulched with maple leaves were injured in each of 8 years. New fall seedings mulched with either peat or well-shaken wheat straw presented improvement in condition as indicated by shade of green and quantity of growth.

When resort was made to artificial watering, 8,000 to 10,000 gallons of water per 1,000 square feet per season were required on Wooster silt loam soil.

Under Ohio soil and climatic conditions the number of grasses suitable for lawn purposes is limited to a few. Of this small number, Kentucky bluegrass is more universally adapted and more generally grown than any other. It is possible to make a very beautiful lawn with creeping bent, but to bring it to perfection requires much care, more than most people can give.

The nitrogen removed by three strains of creeping bent, Metropolitan, Virginia, and Washington, amounted on the average to 5 pounds per 1,000 square feet. This average was based on the composition of clippings obtained through three seasons.

For use under trees, Chewings fescue proved far superior to either rough-stalked meadow grass or wood meadow grass. The latter was of little or no value. The superiority of Chewings fescue over rough-stalked meadow grass is probably due to its more extensive and deeper root system.

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